AD 438910

DEFENSE DOCUMENTATION CENTER

FOR

SCIENTIFIC AND TECHNICAL INFORMATION

CAMERON STATION, ALEXANDRIA, VIRGINIA

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

MEMORANDUM REPORT
M64-26-1

438910

UNITED STATES ARMY

FRANKFORD ARSENAL

PYROTECHNIC DELAY DEVICES
FOR
LOW ENERGY DETONATING CORD SYSTEMS

by

J. F. KOWALICK

OMS Code 4110.16.8500.1.20

April 1964

REPORT M64-26-1

PHILADELPHIA, PA. 19137

MEMORANDUM REPORT M64-26-1

PYROTECHNIC DELAY DEVICES FOR LOW ENERGY DETONATING CORD SYSTEMS

OMS Code 4110.16.8500.1.20

Prepared by

J. F. Kowalick

J. F. KOWALICK
Chemical Engineer

Reviewed by

T. Q. Ciccone

T. Q. CICCONE
Chief
Combustion and Detonation Section

Approved by

A. L. Jamieson

A. L. JAMIESON
Deputy Director
Pitman-Dunn Institute for Research

April 1964

FRANKFORD ARSENAL
Research and Development Group
Philadelphia, Pa.

ABSTRACT

A study was initiated to survey the field of pyrotechnic delay devices as such devices pertain to systems where relatively low energy transfer is accomplished through detonating cord having a core of small amounts of high explosive.

Detonating fuse delays developed for use in the blasting industry incorporate powder trains of the sequence - high explosive, to deflagrating composition, to delay composition. Although such delays appear to be in common use, their delay times do not exceed approximately 300 milliseconds and their reliability has not been established.

Furthermore, a design problem may exist in scaling up the delay time to the order of several seconds. Functional descriptions of these delays are presented.

A method is presented for providing a complete seal between detonating cord and the delay device.

References cited, although not all-inclusive, are indicative of current and past interest in this subject.

TABLE OF CONTENTS

INTRODUCTION

In earlier investigations, the adaptability of mild detonating fuse (MDF), a low energy detonating cord, to aircraft escape systems was demonstrated[1*] and simple prototype escape systems with MDF as the energy transfer medium were tested.[2] In the prototype system, a Du Pont nominal 2-second delay element (Figure 1) was substituted for the M5 PAD delay cartridge and was attached to MDF by crimping. This element was light in weight (4.5 grams) and had a reported burning time of 2.0 seconds ± 10 percent.

It was concluded that such delay elements were readily adaptable to an MDF system but, like standard delays used in aircraft escape systems, they would require testing and standardization. A need still exists for a standardized delay of several seconds' duration for use in MDF lines in proposed aircraft escape systems.

CLASSIFICATION OF DETONATING FUSE DELAYS

It is convenient to classify detonating fuse delays reported in publications and in letter patents into two categories: (1) those having a mechanical barrier between the detonating cord and the delay composition; and (2) those having a continuous explosive and/or propellant train between the detonating cord and the delay composition. The former category includes barriers that act as firing pins, thereby initiating a primary explosive by percussion in a delay unit.

Percussion Barriers

A delay train which is initiated by percussion of a primer containing high explosive can be fabricated by modifying any number of existing delays to MDF-initiated percussion delays. Examples of such delays are the MK-13-0 (Figure 2), a 1.5-second delay element,[3] the MK-14-0, a 1.6-second delay,[4] and a host of delays described in the journal of the JANAF Fuse Committee.[5]

The train from primary explosive to delay composition in these delays invariably involves the use of baffles or porous media as "softening" agents. (Note baffling in Figure 2.) A description and sketch of the MK-10 Mod 0 delay element, suitable for direct percussion-ignition by detonating cord, is presented in Figure 3.

*See REFERENCES.

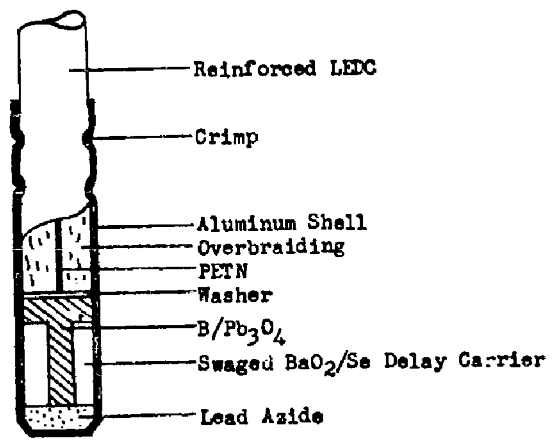


Figure 1. DuPont 2-second Delay

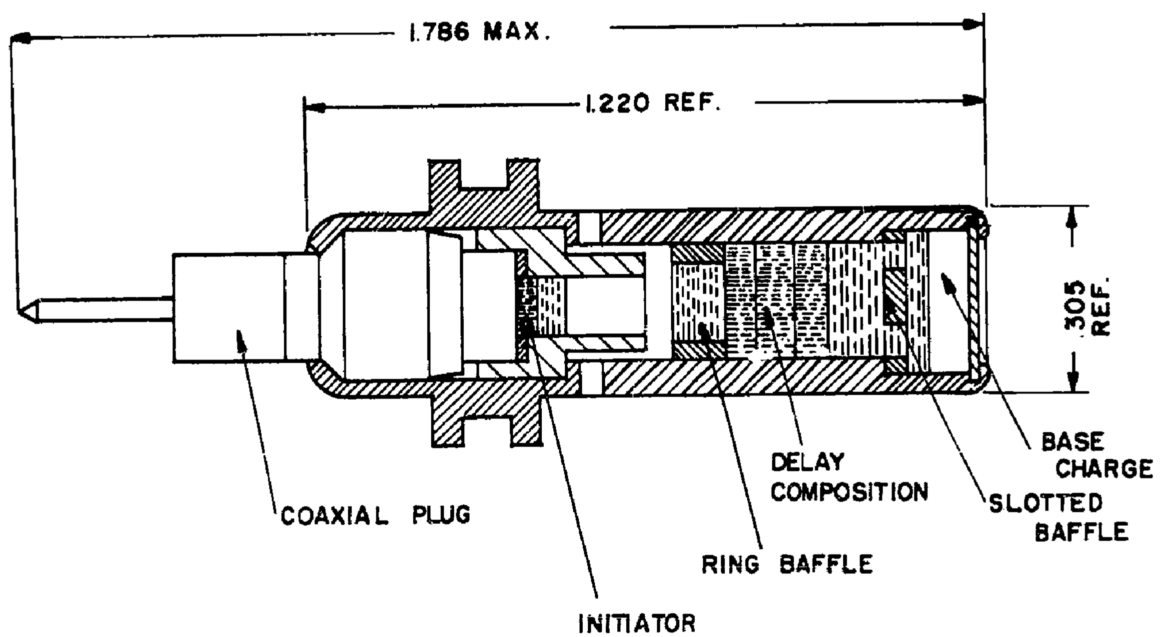
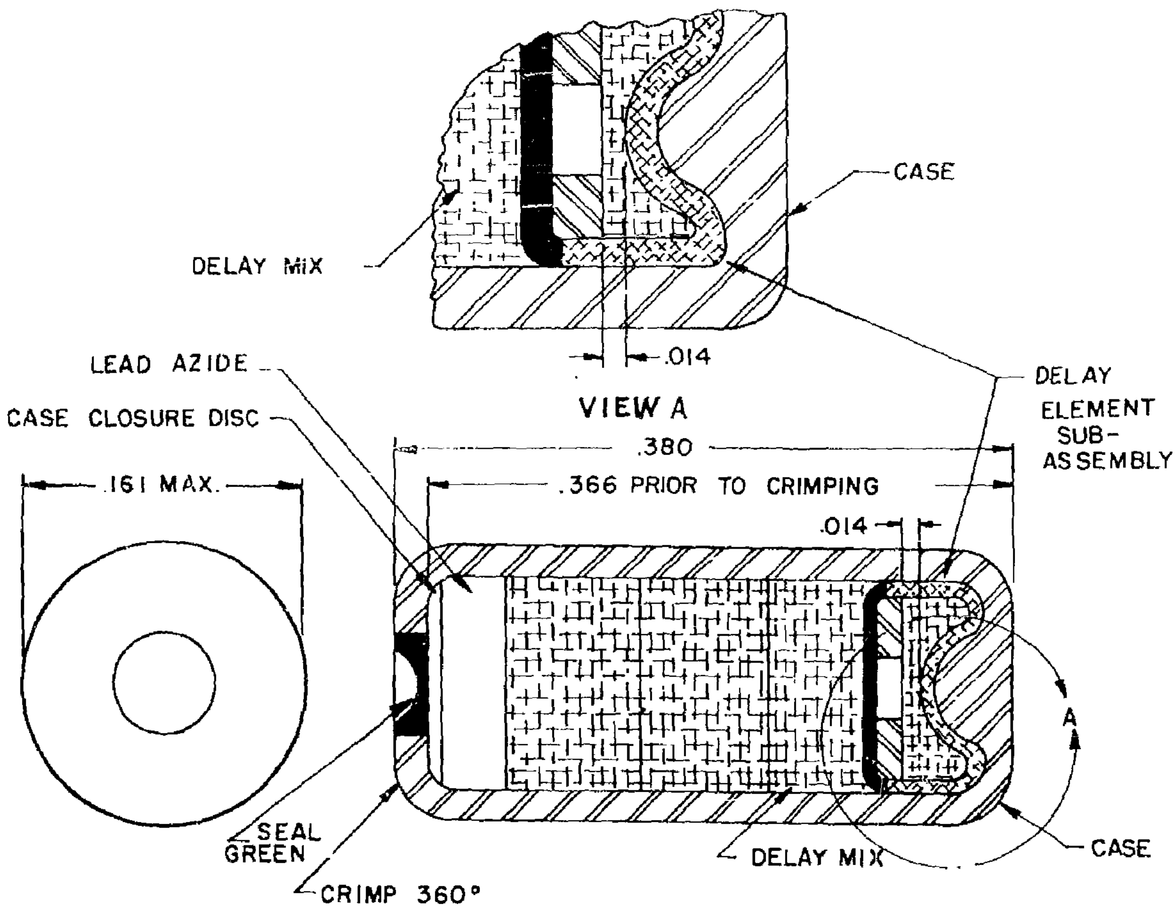


Figure 2. Actuator Delay, MK 13-0



This is a 600-microsecond delay which was designed for use in the MK 176 Fuze for the 2.75 in. Folding Fin Aircraft Rocket. In essence, the delay element subassembly depiced in drawing 652212 is a percussion primer. Firing of this delay is accomplished by driving a diaphragm in the fuze rotor against the end of the delay element. Driving force is derived from firing a stab primer (MK 125 Mod 1) upon fuze contact with the target.

Figure 3. Delay Element, MK 10, Mod 0

Explosive-Propellant Train Delays

The design technology of pyrotechnic and explosive trains, although highly developed, is largely empirical. Therefore, in designing for a new application it is very helpful to consider past designs that have functioned with some degree of success. Although letter patents[6,7,8,9,10,11] describe a number of powder-train delay devices for use in detonating fuse lines, they are limited to delay intervals of from 20 to 300 milliseconds.*

A typical design[6] (Figure 4) describes a delay which is symmetrical and can be used with PETN detonating cord. The detonating propagates from the detonating cord (fuse) to a primary explosive, such as lead azide, which is housed in a funneled lead cylinder. The inside wall along the funnel absorbs much of the shock, permitting a transfer to deflagration of a relatively gasless composition, such as boron/potassium nitrate or lead dioxide/silicon. This composition burns up to a baffle washer which prevents the delay composition from dispersing, yet allows it to ignite. The delay mixture was smokeless powder/$KClO_4$/lead sulfocyanate. It is claimed that this device functions in either direction, with a delay time range of 20 to 30 milliseconds. No reliability data are reported.

Another patent[7] suggests a method for incorporating a delay of several seconds into a detonating fuse line. Figure 5 shows the suggested sequence - from detonating fuse to blasting cap, to a transmission line (consisting of impregnated black powder in a woven fabric), to a delay composition (such as red lead/silicon/black powder/oxidizer), through a baffle to a blasting cap, and back to detonating fuse.

Patents 2,707,439,[8] "Short Interval Delay Blasting Device," and 2,841,476,[9] "Delay Blasting Device," are similar in scope to the device shown in Figure 4. A patent[10] by H. A. Lewis et al, "Blasting Explosive Device," cites examples of six blasting delays varying in operation time from three to 353 milliseconds. Four different designs are sketched, and a tabulation is presented showing delay times for variations in mechanical components and compositions.

A patent[11] by F. H. G. McCaffrey describes a nominal 50-millisecond delay device which would have a time deviation of ±11 milliseconds from the mean value in greater than 99 percent of the cases.**

*Title pages of patents described in this section are included in the Appendix.

**Temperature of functioning is not indicated.

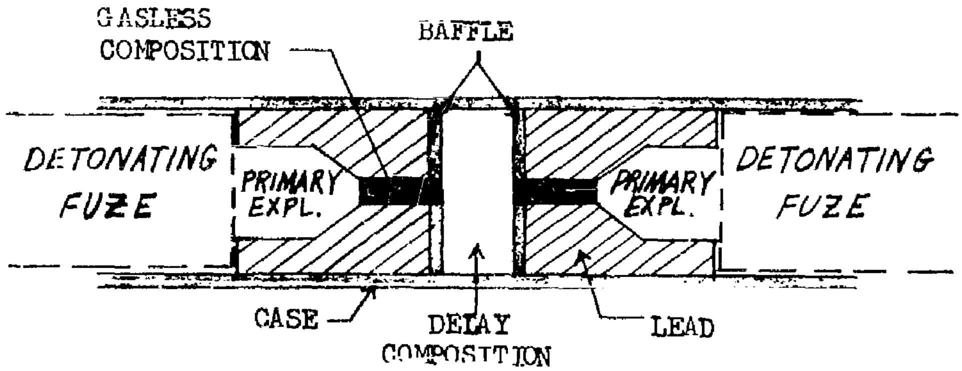


Figure 4. Typical Delay Design (Patent No. 2,707,438)

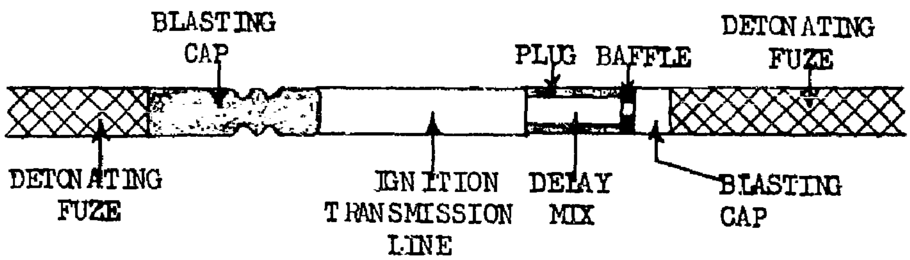


Figure 5. Delay sequence, using Ignition Transmission Line

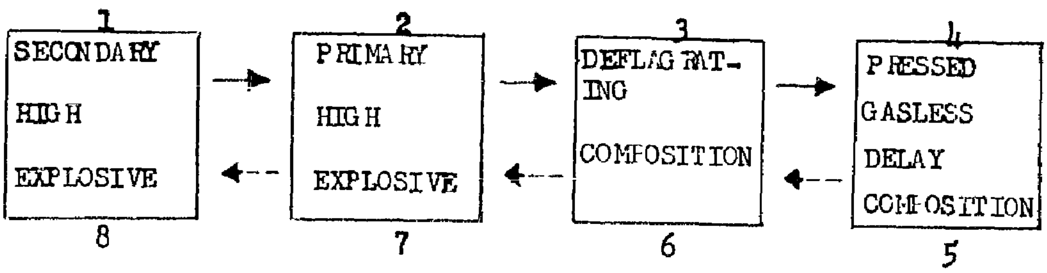


Figure 6. Series Arrangement in Blasting Delays

TRANSITION FROM DETONATION TO DEFLAGRATION

The relative ease of the transition from a detonating explosive to a deflagrating pyrotechnic delay mixture - a transition required in powder-train delays for detonating cord systems - depends heavily upon the composition of the detonating explosive. This transition has generally been accomplished in delay blasting devices by the series arrangement, as indicated by solid arrows in Figure 6. A similar transition back to detonation generally occurs in the reverse direction, as indicated by the dashed arrows.

The sequence $1 \rightarrow 8$ is the basis for the design of many 2-way delays (i.e., initiated from either end) for use in detonating fuse lines. In such delays the secondary high explosive is ordinarily PETN, TNT, or RDX, while either lead azide or mercury fulminate are suitable as primary explosives.

In some cases the deflagrating composition may be omitted, although the extent of baffling between steps 2 and 4 must be adequate to prevent "blow through." Where a deflagrating composition is employed, black powder, a mixture of smokeless powder/potassium chlorate/ lead sulfocyanate, or mixtures such as magnesium/barium peroxide/ selenium, and bismuth/selenium/potassium chlorate, are common.

Itemization of the large number of gasless delay compositions that may be used is beyond the scope of this report.

SEALING OF DELAY UNITS

Shock-Pass Heat Filters

The usefulness of shock-pass heat filters (SPHF) in MDF delays becomes apparent in systems where it is desirable to have a hermetic seal between the MDF and the delay composition. It is well known[12] that detonation can be propagated through steel and glass plates if the plate thickness is less than a certain critical value, S_c. For thicknesses greater than S_c, detonation cannot re-form on the opposite side of a plate impacted on one side by a detonation wave in a given charge. For a thickness less than S_c, detonation will re-form on the opposite side of the plate at a point which is of variable distance away from the plate. The re-formation time, T, of the detonation can be calculated from the relation

$$T = \Delta t - S_1 / V^* = T_a + S_1 \left(\frac{1}{D} - \frac{1}{V^*} \right)$$

where Δt is the observed total elapsed time between the incident collision on one side of the plate and the re-formation of detonation in the explosive on the opposite side;

S_1 is a thickness less than the critical value, S_c;

V^* is the average shock velocity across the plate;

T_a is the apparent time lag determined by simply extending the time-distance streak-camera trace of the incident wave and determining the displacement from it of the re-formed detonation wave along the time axis (the trace of Figure 7 is for SPHF initiation of Composition B at $S_1/S_c \sim 0.75$);

D is the detonation velocity in the explosive used.

Although the magnitude of T_a (0.21 to 3.10 μsec through steel and glass plates for 5.08 and 7.62 cm in diameter of Composition B, with $S_1 << S_c$) does not place shock-pass heat filters in the category of delays, they would have separate merit as sealing devices, not only in MDF delays but also in other components initiated by MDF in the through-bulkhead fashion (as in Figure 8).

The possibility of utilizing moving postons for sealing between MDF and the delay is good. For example, the design shown in Figure 9 employs Bridgeman's unsupported area principle to seal the MDF core volume after functioning.

DISCUSSION

Because there has been little or no demand in the past for delays of several seconds in low energy detonating cord systems, few developmental efforts on such devices have been reported. However, detonating fuse delay devices with delay times in the range of 20 to 300 milliseconds have been developed for use in the blasting industry. Such devices, with appropriate modifications, hold promise for use as low energy detonating cord delays with delay times of several seconds.

Scaling up the delay time from milliseconds to seconds will involve modifications in the basic design. This involves not only establishing a proper delay column length, but also maintaining effective and reliable detonation-to-deflagration transition. Determining such factors as baffle size, shape, and composition is largely empirical, but design technology in this area is highly developed.

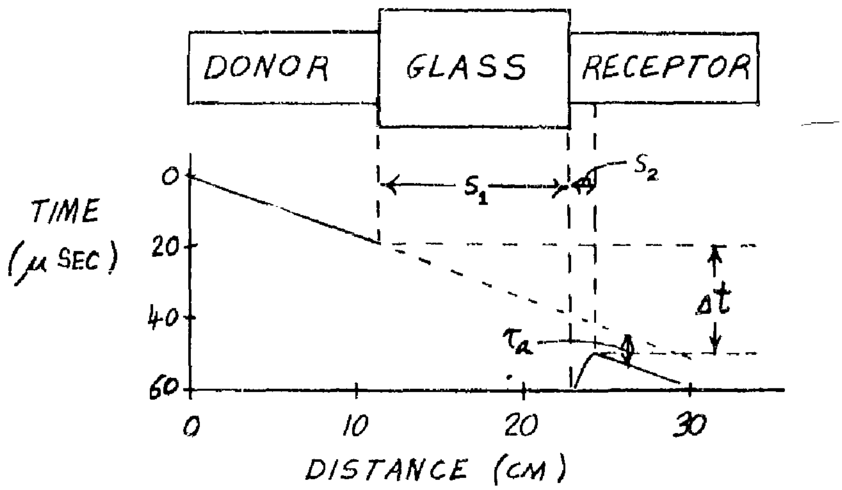


Figure 7. Time-Distance Shock-Pass Heat Filter (SPHF) Trace

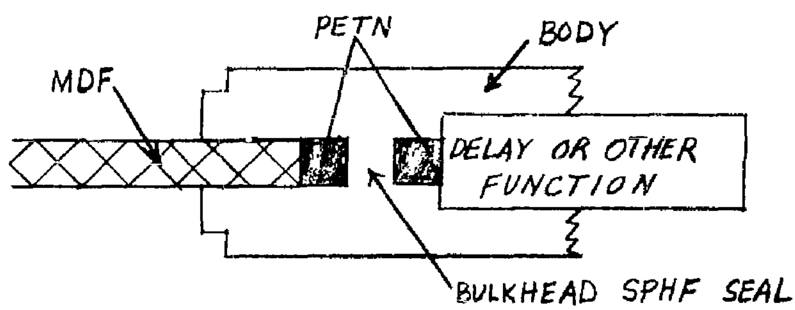


Figure 8. Example of a typical Thru-Bulkhead Ignition

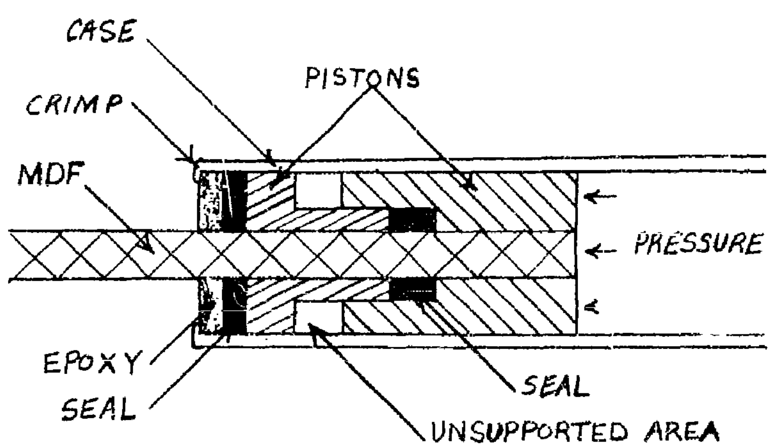


Figure 9. MDF Delay Seal

Shock-pass heat filters (SPHF) offer a convenient means for providing a complete seal between detonating cord and a delay device. Mathematical descriptions of SPHF's have been supported by a large amount of experimental data.

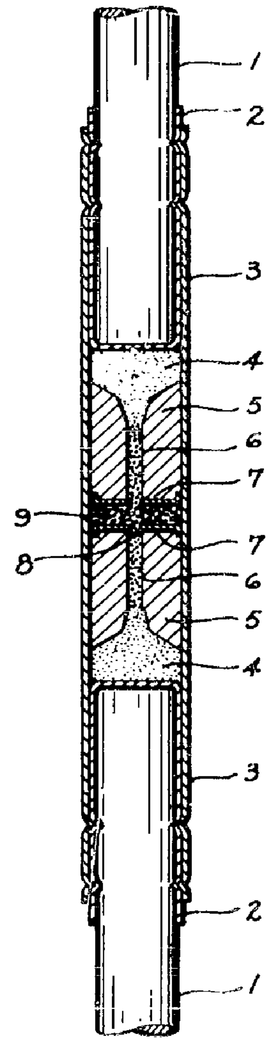
APPENDIX

DELAY DEVICES PATENTED

May 3, 1955 W. MANN ET AL **2,707,438**

SHORT INTERVAL DELAY BLASTING DEVICE

Filed May 26, 1954



INVENTORS

WILLIAM MANN &
GORDON TOWELL

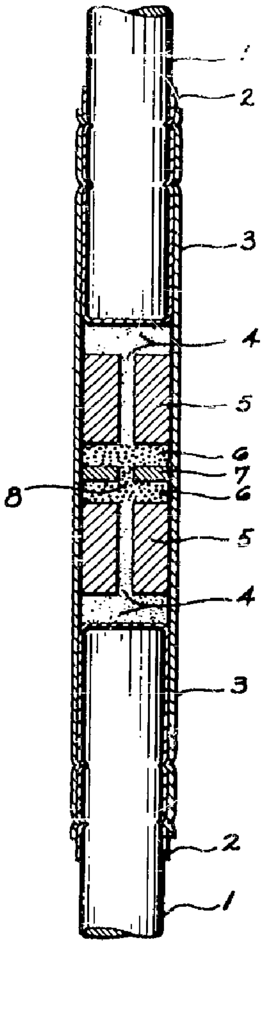
BY Bernard J. Rowan[?]

AGENT

May 3, 1955 W. E. HAMILTON 2,707,439

SHORT INTERVAL DELAY BLASTING DEVICE

Filed May 26, 1954



INVENTOR.

WILLIAM E. HAMILTON

BY Bernard J. Rosen

AGENT

BLASTING EXPLOSIVE DEVICE

Filed April 17, 1951

FIG. 1.

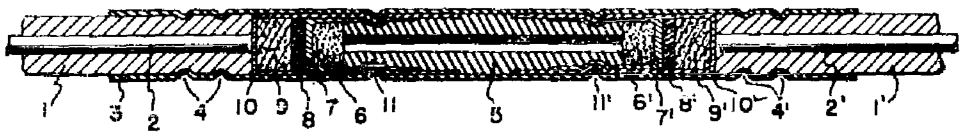


FIG. 2.

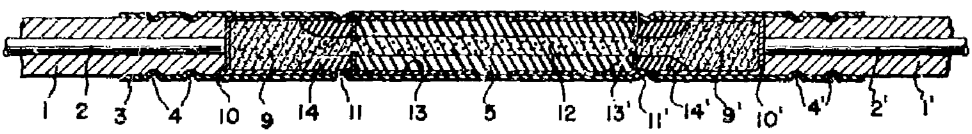


FIG. 3.

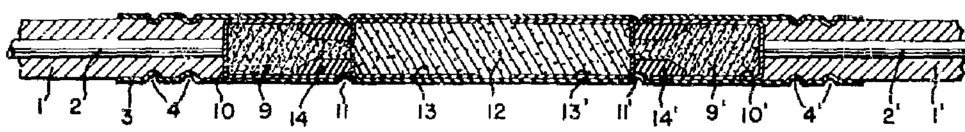


FIG. 4.

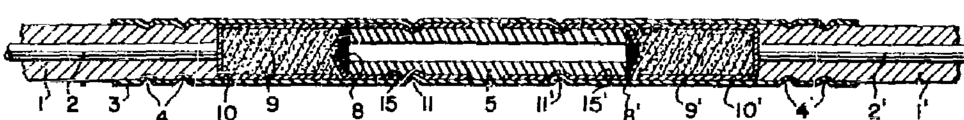


FIG. 5.

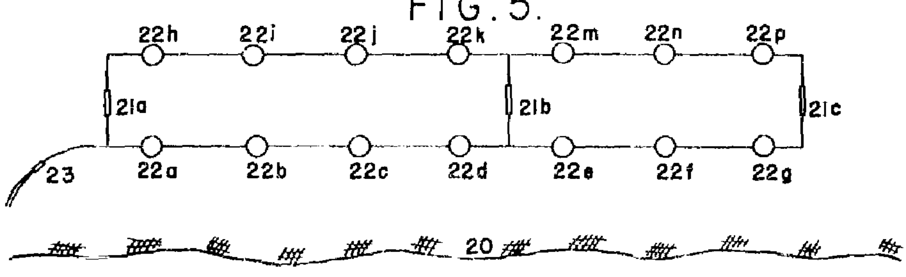
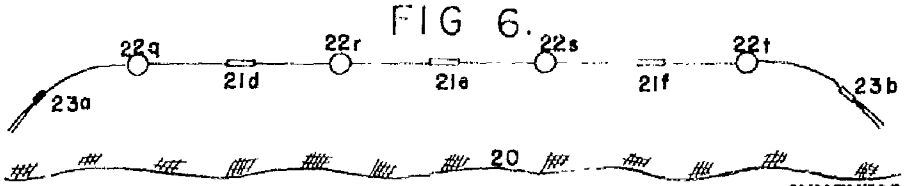


FIG 6.



INVENTORS:
HAROLD ARTHUR LEWIS and
GEORGE ADELBERT NODDIN

BY Thos. A. Wilson
Joseph J. Heimbach
ATTORNEYS.

SHORT INTERVAL DELAY BLASTING DEVICE

Filed March 9, 1956 3 Sheets-Sheet 1

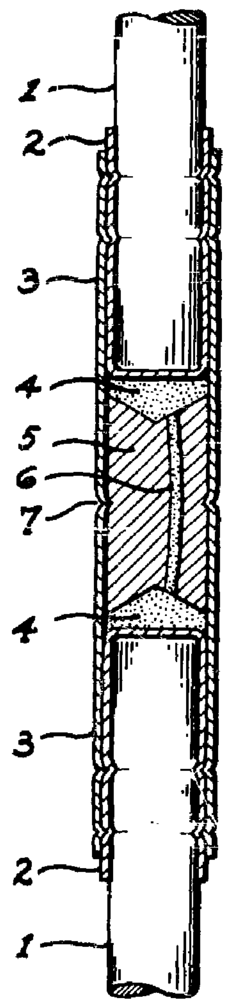


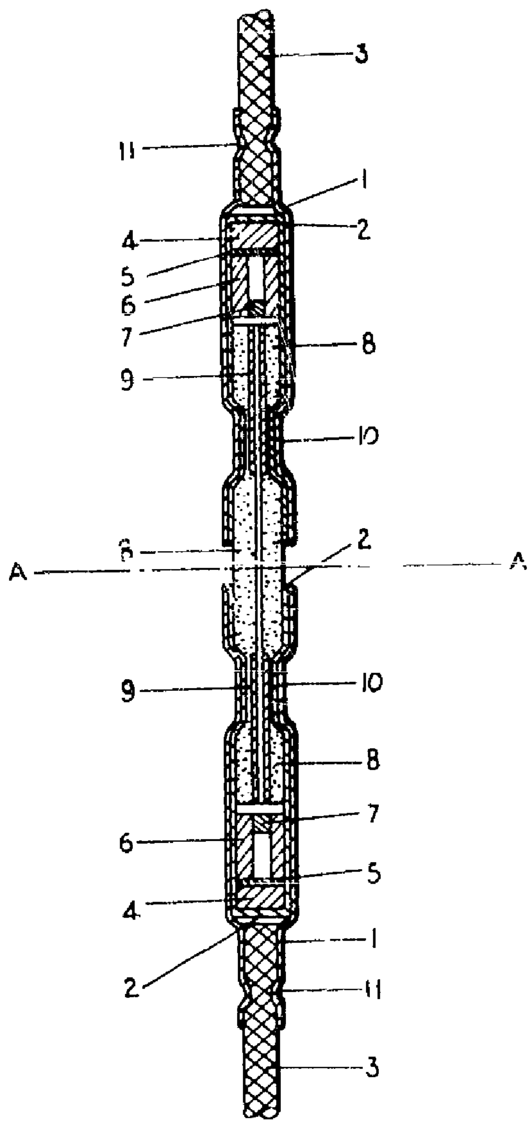
Fig. 1

INVENTORS
FRANCIS H. G. McCAFFREY,
WILLIAM E. HAMILTON
BY Bernard F. Rosen
AGENT

June 23, 1959 W. FORSYTH 2,891,476

DELAY BLASTING DEVICES

Filed March 15, 1956



INVENTOR

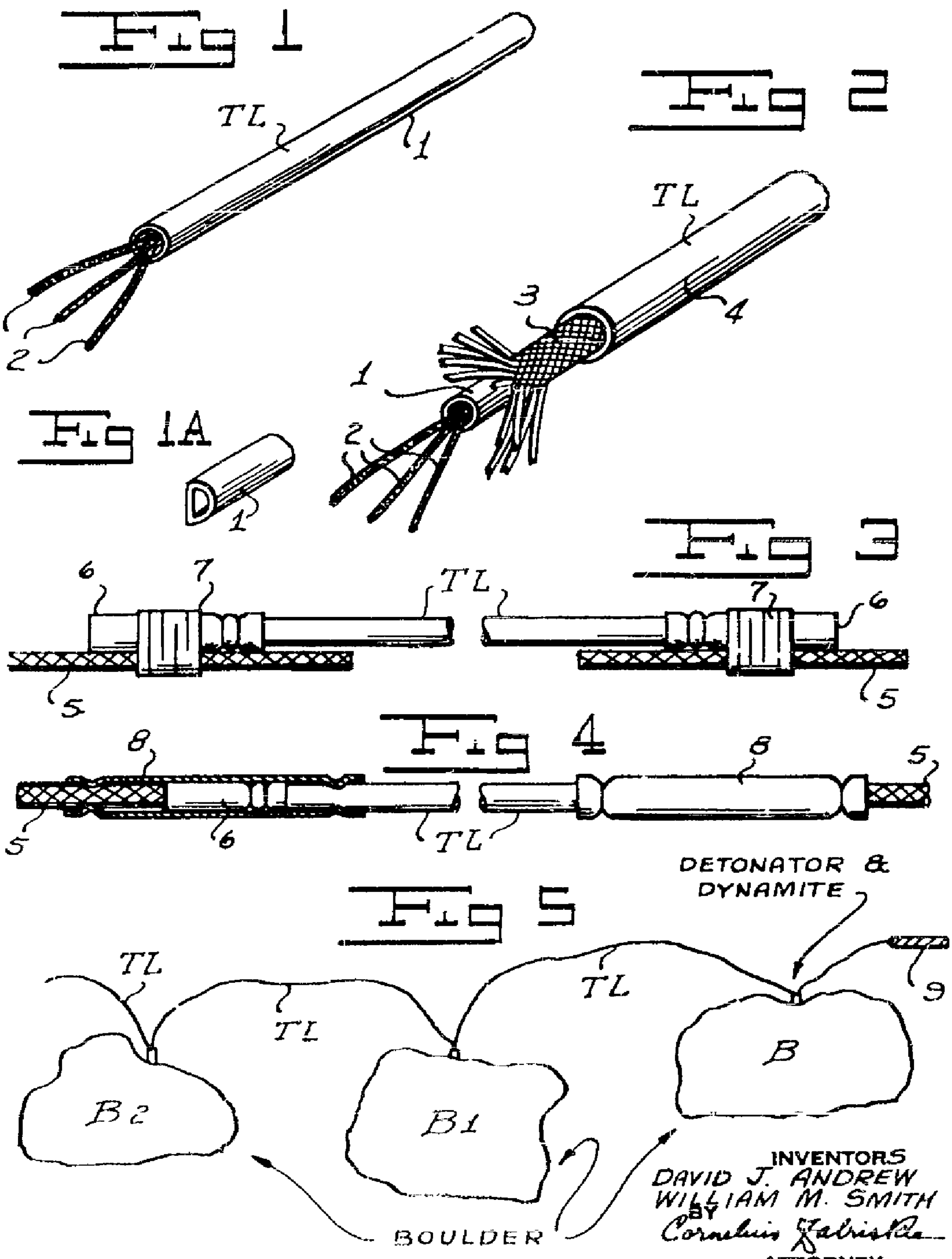
William Forsyth

Cushman Darby & Cushman

ATTORNEYS

IGNITION TRANSMISSION LINE AND SYSTEMS INCLUDING THE SAME

Filed July 26, 1957 2 Sheets-Sheet 1



INVENTORS
DAVID J. ANDREW
WILLIAM M. SMITH
BY
Cornelius Zabriskie
ATTORNEY

REFERENCES

1. T. Q. Ciccone and R. S. Shulman, "Preliminary Studies to Determine Applicability of Low Energy Detonating Cord (LEDC) to Aircraft Escape Systems," Frankford Arsenal Memorandum Report MR-670, April 1958.

2. R. S. Shulman, "Studies of a Typical Aircraft Escape System Based upon Low Energy Detonating Cord (LEDC)," Frankford Arsenal Memorandum Report M60-19-1, Jan 1960.

3. "Development of XE-18A Actuator, Explosive, for the XB-74B and XB-18A Bomb Fuzes" (U), NAVORD 6044, 28 January 1958. (CONFIDENTIAL)

4. "Evaluation of the MK-14-MOD-0 Actuator," NOLTR 62-8, 17 January 1962.

5. "A Compendium of Pyrotechnic Delay Devices," Journal JANAF Fuze Committee, Serial #31, 23 Oct 1963.

6. William Mann and Gordon Towell, "Short Interval Delay Blasting Device," U.S. Patent 2,707,438, 3 May 1955.

7. David J. Andrew and William M. Smith, "Ignition Transmission Line and Systems Including the Same," U.S. Patent 2,923,239, 2 Feb 1960.

8. William E. Hamilton, "Short Interval Delay Blasting Device," U.S. Patent 2,707,439, 3 May 1955.

9. William Forsyth, "Delay Blasting Devices," U.S. Patent 2,891,476, 23 June 1959.

10. Harold Arthur Lewis and George Adelbert Noddin, "Blasting Explosive Device," U.S. Patent 2,736,263, 28 Feb 1956.

11. Francis H. G. McCaffrey and William E. Hamilton, "Short Interval Delay Blasting Device," U.S.Patent 2,796,834, 25 June 1957.

12. Melvin A. Cook, <u>The Science of High Explosives</u>, New York: Reinhold Publishing Co., pp 83-89, 187-194, 1958.

DISTRIBUTION

U.S.Army

1 - Hq, U.S.Army Materiel Command
Attn: AMCRD-DE-W
Washington, D. C. 20315

1 - Attn: AMCRD-DE-MO

1 - Attn: AMCPM

1 - Commanding General
U.S.Army Munitians Command
Attn: AMSMU-RE-R
Picatinny Arsenal
Dover, New Jersey 07801

1 - Attn: AMSMU-RE-E

1 - Attn: AMSMU-RE-EA

1 - Attn: AMSMU-RE-EE

1 - Attn: AMSMU-RE-S

1 - Attn: AMSMU-LC
CDC Liaison Officer

1 - Attn: AMSMU-LM, U.S.Marine
Corps Liaison Officer

1 - Commanding General
U.S.Army Mobility Command
Attn: Directorate of Research &
Development, AMSMO-R
Warren,
Mich. 48090.

1 - Attn: AMSMO-RR

1 - Attn: AMSMO-RD

1 - Attn: AMSMO-RL

1 - Attn: AMSMO-PR

1 - Attn: Liaison Office, CDC

1 - Commanding General
U.S.Army Test and Evaluation
Command
Attn: Director of Aviation
Materiel Testing
Aberdeen Proving Ground, Md. 21005

1 - Attn: Director of General
Equipment Testing

1 - Attn: Liaison Office, CDC

2 - Attn: Technical Library

1 - Commanding General
U.S.Army Weapons Command
Attn: Chief Scientist, AMSWE-SAS
Rock Island Arsenal
Rock Island, Illinois 61202

1 - Commanding General
U.S.Army Missile Command
Attn: Director, Research and
Development Directorate
Redstone Arsenal
Huntsville, Alabama 35809

1 - Commanding General
U.S.Army Electronics Command
Attn: Director of Research and
Development, AMSEL-RD
Fort Monmouth, New Jersey 07703

1 - Commanding General
U.S.Army Supply and
Maintenance Command
Attn: Director of Maintenance
AMSSM-M
Washington 25, D. C.

1 - Attn: Director of Supply
AMSSM-S

1 - U.S.Army Natick Laboratory
Attn: AMXRE-AAE
Natick, Massachusetts

1 - Commanding General
U.S.Army Aviation and Surface Materiel Command
Attn: Technical Director
P. O. Box 209, Main Office
St. Louis, Missouri 63166

1 - Attn: Director, Engineering

1 - Attn: Liaison Office, CDC

1 - Commanding General
U.S.Army Combat Development Command
Attn: Scientific Advisor, CDCSA
Fort Belvoir, Virginia 22060

1 - Attn: Director, Operations Research & Experimental, CDCRE

1 - Attn: Director, Plans, Programs, & Intelligence, CDCPI

1 - Attn: Director, Concepts & Doctrine Development CDCCD

1 - Attn: Director, Materiel Requirements, CDCMR

1 - Attn: Director, Doctrine & Organization Media, CDCDM

1 - Commanding Officer
Rock Island Arsenal
Attn: Technical Director
Rock Island, Illinois 61202

1 - Attn: Chief, Design Engineering Branch, SWERI-RDD

1 - Commanding Officer
Picatinny Arsenal
Attn: Technical Director
Dover, New Jersey 07801

1 - Commanding Officer
U.S.Army Research and Development Laboratory
Attn: Technical Director
Edgewood Arsenal, Maryland 21010

1 - Commanding Officer
U.S.Army Research Office-Durham
Attn; CRD-AA-E
Box CM, Duke Station
Durham, North Carolina 27706

1 - Attn: CRD-AA-X

1 - U.S.Army Field Office, USAFSSD
Bldg #1, Room 250
5730 Arbor Vitae Blvd.
Inglewood, California

1 - Commanding Officer
Harry Diamond Laboratories
Attn: Technical Director
Washington, D. C. 20438

1 - Attn: AMXDO-TIB

1 - Commanding Officer
U.S.Army Aviation Center
Attn: Director, USAATBG
Fort Rucker, Alabama

1 - Attn: Director, USAATHRE

1 - Attn: Director, USABAAR

1 - Commanding Officer
U.S.Army Transportation Research Command
Attn: Technical Director
Fort Eustis, Virginia

National Aeronautics and Space Administration

1 - Dir, NASA Langley Research Center
Attn: Mrs. E.R.Gilman, Librarian
Langley Station
Hampton, Virginia, 23365

1 - Director, NASA Geroge C.
Marshall Space Flight Center
Attn: Saturn System Office
Huntsville, Alabama 35809

1 - [illegible]

1 - Attn: Propulsion and Energy
Division

1 - Attn: Future Projects Office

1 - Attn: Research Projects Office

1 - Director, NASA Manned Space-
craft Center
Attn: Gemini Spacecraft
Projects Office
Houston 1, Texas 77058

2 - Attn: Mr. Chas. M. Grant, Jr.
Chief, Technical Informa-
tion Division, Code ACI

2 - Attn: Apollo Spacecraft
Projects Office

1 - Attn: Office of Asst Director,
Research * Development

1 - Attn: Spacecraft Research Div

1 - Attn: Crew System Division

1 - Director
NASA Goddard Space Flight Center
Greenbelt, Maryland

1 - Director
NASA Jet Propulsion Laboratory
Pasadena, Calif.

1 - Director
NASA Lewis Research Center
Cleveland, Ohio 44111

U.S.Navy

1 - Chief, Bureau of Naval Weapons
Department of the Navy
Attn: RMMO
Washington 25, D. C.

1 - Attn: RMMP

1 - Commanding Officer
U.S.Naval Weapons Laboratory
Attn: Mr. R. I. Rossbacher,
Code WC
Dahlgren, Virginia

1 - Commanding Officer
U.S.Naval Ordnance Test Station
Attn: D. H. Strietzel
Code 4574
China Lake, Calif. 93557

1 - Commanding Officer
U.S.Naval Ordnance Plant
Attn: Code PD-270
Macon, Georgia

1 - Commanding Officer
Naval Air Depot-Crane
Attn: Code 4100
Crane, Indiana

1 - Director
Air Crew Equipment Laboratory
Naval Air Engineering Center
Attn: C. T. Koochembere,
Group Manager
Philadelphia, Pa. 19112

1 - Commander
Naval Air Development Center
Attn: Technical Library
Johnsville, Pennsylvania

U.S.Air Force

3 - Commander
Aeronautical Systems Division
Attn: ASNRMF-24, Mr. R. Dobbek
Wright-Patterson AFB, Ohio
45433

3 - Commander
Aeronautical Systems Division
Attn: ASNMES, C. K. Hodell
Wright-Patterson AFB, Ohio 45433

1 - Attn: ASNMEP, Mr. A. E. Varble

1 - Attn: ASNMEP, C. E. Grindstaff

1 - Attn: ASLJM, Mr. E. Dock

1 - Attn: ASZWO, Capt F. H. Briggs

1 - Attn: ASZFO-A

1

1 - Attn: ASNRH, Mr. Geo. C. Dickson

1 - Attn: ASBMB, Maj N. P. Clarke

1 - Attn: ASWMRD, Mr. W. M. Cheslak

1 - Attn: ASNXRR-Library

1 - Attn: ASZB, Col C. A. Gayle

1 - Directorate of Aerospace Safety
Attn: Chief, Life Sciences Group
AFIAS-L
Norton Air Force Base, Calif.
92409

1 - Commander
Ogden Air Materiel Area
Attn: OONEAA
Hill Air Force Base Utah

1 - Commander
2705th Airmunitions Wing (AMC)
Attn: OOYTC
Hill Air Force Base, Utah

1 - Commander
Edwards Air Force Base
Attn: AFRPL (RPMM)
Edwards, Calif. 93523

1 - USAF Special Weapons Center
Attn: SWOI
Kirtland Air Force Base, N. M.

OTHER

20 - Defense Documentation Center
Cameron Station
Alexandria, Virginia 22314

1 - Chemical Propulsion Information
Agency
Johns Hopkins University
Silver Spring, Maryland

2 - Scientific and Technical
Information Facility
Attn: NASA Representative
(S-AK/DL)
P.O. Box 5700
Bethesda, Maryland 20014

1 - U.S.Army Liaison Office
U.S.Naval School
Explosive Ordnance Disposal
U.S.Naval Propellant Plant
Indian Head, Md.

COMMERCIAL FACILITIES

1 - Aircraft Armaments, Inc.,
Cockeysville, Md.

1 - Armour Research Foundation
Illinois Institute of Technology
10 W. 35th St.
Chicago 16, Ill.

1 - Atlantic Research Corporation
Shirley Highway at Edsall Rd.
Alexandria, Va.

1 - Bell Aerosystems Corporation
P.O. Box 1
Buffalo, N. Y.

1 - The Boeing Company
Aerospace Division
P.O. Box 3707
Seattle 24, Washington

1 - The Boeing Airplane Co.
Wichita, Kansas
Attn: Mr. McNary

1 - CONVAIR
Fort Worth, Texas
Attn: Mr. W. E.Early, Jr.

1 - Convair
San Diego, Calif.
Attn: Mr. Hugo Mohrlock
Project Office

1 - Douglas Aircraft Co., Inc.
El Segundo, Calif.
Attn: Mr. H. A. Hummel,
Equip & Int Group

1 - Douglas Aircraft Co., Inc.
3855 Lakewood Blvd
P. O. Box 200
Long Beach, Calif.
Attn: Mr. Fred Walcott

1 - Douglas Aircraft Co., Inc.
P. O., Box 1017
Tulsa, Okla.

1 - Ensing-Bickford Co.,
Simsbury, Conn.
Attn: Mr. W. Smith
Mgr, Explosives Res.

1 - General Dynamics/Astronautics
5001 Kearney Villa Rd
P. O. Box 1128
San Diego, Calif.

1 - General Dynamics/Fort Worth
P. O. Box 748
Fort Worth, Texas

1 - Goodyear Aircraft Corporation
1210 Massillon Rd
Akron 15, Ohio

1 - Grumman Aircraft Engineering Corp.
Bethpage, Long Island, N. Y.

1 - Hercules Powder Company
Chemical Propulsion Division
Wilmington, Del.

1 - Holex, Incorporated
Hollister, Calif.
Attn: Mr. S. A. Moses

1 - Ling-Tempco-Vought Corp.
Astronautics Division
Dallas, Texas

1 - Lockheed Aircraft Corporation
California Division
Burbank, Calif.
Attn: Mr. R. A. Bailey,Ch Engineer

1 - Lockheed Aircraft Corporation
VanNuys, Calif.
Attn: Mr. J. Gurskis, Jr.
Missile & Space Div.

1 - Lockheed Missiles & Space Co.
Sunnyvale, Calif.

1 - The Martin Company
Baltimore 3, Md.

1 - McDonnell Aircraft Corporation
P. O. Box 516
St. Louis 66, Mo.
Attn: Mr. V. Drexelius

1 - McCormick-Selph Corp.
Hollister Airport
Hollister, Calif.
Attn: Mr. R. Allen
Mgr, Explosives Dept.

1 - North American Aviation, Inc.,
Columbus, Ohio
Attn: Mr. Wm. Hart

1 - North American Aviation, Inc.
International Airport
Los Angeles 45, Calif.
Attn: Mr. Heidinger

1 - Northrop Corporation
NORAIR Division
1001 E. Broadway
Hawthorne, Calif.
Attn: Mr. N. E. Good, Suprv,
Armament Installations,
Dept 3458

1 - Ordnance Associates
Engineering Information Dept.
855 El Centro St.
South Pasadena, Calif.
Attn: Mr. D. Andrew, President

1 - Ordnance Engineering Associates, Inc.
1030 E. North Ave
De Plaines, Ill.
Attn: Mr. A. D. Kafadar, President

1 - Republic Aviation Corp.
Farmingdale, Long Island, N. Y.

1 - Rocket Power, Inc.
Falcon Field,
Mesa, Ariz.

1 - Stanley Aviation Corp.
2501 Dallas St
Denver, Colo.

1 - Talley Industries
3402 W. Century Blvd.
Inglewood, Calif.

1 - Thiokol Chemical Corporation
Bristol Division
Bristol, Penna.

1 - Weber Aircraft Corporation
2820 Ontario St.
Burbank, Calif.

Reproduction Branch
FRANKFORD ARSENAL
Date Printed:- 5/14/64

AD- ACCESSION NO.

FRANKFORD ARSENAL, Research and Development Group, Pitman-Dunn Institute for Research, Philadelphia, Pa.

PYROTECHNIC DELAY DEVICES FOR LOW ENERGY DETONATING CORD SYSTEMS by J. F. Kowalick

Unclassified Report

FA Rpt M64-26-1, Apr 64; 22 pp incl illustrations

OMS Code 4110.16.8500.1.20

A study was initiated to survey the field of pyrotechnic delay devices as they pertain to systems where relatively low energy transfer is accomplished through detonating cord having a core of small amounts of high explosive. Detonating fuse delays developed for use in the blasting industry incorporate powder trains of the sequence - high explosive to deflagrating composition, to delay composition. Although such delays appear to be in common use, their delay times do not exceed approximately 300 msec, and their reliability has not been established.

Furthermore, a design problem may exist in scaling up the delay time to the order of several seconds. Functional descriptions of these delays are presented. A method is presented for providing a complete seal between detonating cord and the delay device.

References cited, although not all-inclusive, are indicative of current and past interest in this subject.

UNCLASSIFIED

1. Aircraft Escape Systems
2. LEDC
3. Delays

I. FA Rpt M64-26-1, Apr 64
II. J. F. Kowalick
III. OMS Code 4110.16.8500.1.20

DISTRIBUTION LIMITATIONS:
None; obtain copies from DDC.

UNCLASSIFIED

AD- ACCESSION NO.

FRANKFORD ARSENAL, Research and Development Group, Pitman-Dunn Institute for Research, Philadelphia, Pa.

PYROTECHNIC DELAY DEVICES FOR LOW ENERGY DETONATING CORD SYSTEMS by J. F. Kowalick

Unclassified Report

FA Rpt M64-26-1, Apr 64; 22 pp incl illustrations

OMS Code 4110.16.8500.1.20

A study was initiated to survey the field of pyrotechnic delay devices as they pertain to systems where relatively low energy transfer is accomplished through detonating cord having a core of small amounts of high explosive. Detonating fuse delays developed for use in the blasting industry incorporate powder trains of the sequence - high explosive to deflagrating composition, to delay composition. Although such delays appear to be in common use, their delay times do not exceed approximately 300 msec, and their reliability has not been established.

Furthermore, a design problem may exist in scaling up the delay time to the order of several seconds. Functional descriptions of these delays are presented. A method is presented for providing a complete seal between detonating cord and the delay device.

References cited, although not all-inclusive, are indicative of current and past interest in this subject.

UNCLASSIFIED

1. Aircraft Escape Systems
2. LEDC
3. Delays

I. FA Rpt M64-26-1, Apr 64
II. J. F. Kowalick
III. OMS Code 4110.16.8500.1.20

DISTRIBUTION LIMITATIONS:
None; obtain copies from DDC.

UNCLASSIFIED

AD- ACCESSION NO.

FRANKFORD ARSENAL, Research and Development Group, Pitman-Dunn Institute for Research, Philadelphia, Pa.

PYROTECHNIC DELAY DEVICES FOR LOW ENERGY DETONATING CORD SYSTEMS by J. F. Kowalick

Unclassified Report

FA Rpt M64-26-1, Apr 64; 22 pp incl illustrations

OMS Code 4110.16.8500.1.20

A study was initiated to survey the field of pyrotechnic delay devices as they pertain to systems where relatively low energy transfer is accomplished through detonating cord having a core of small amounts of high explosive. Detonating fuse delays developed for use in the blasting industry incorporate powder trains of the sequence - high explosive to deflagrating composition, to delay composition. Although such delays appear to be in common use, their delay times do not exceed approximately 300 msec, and their reliability has not been established.

Furthermore, a design problem may exist in scaling up the delay time to the order of several seconds. Functional descriptions of these delays are presented. A method is presented for providing a complete seal between detonating cord and the delay device.

References cited, although not all-inclusive, are indicative of current and past interest in this subject.

UNCLASSIFIED

1. Aircraft Escape Systems
2. LEDC
3. Delays

I. FA Rpt M64-26-1, Apr 64
II. J. F. Kowalick
III. OMS Code 4110.16.8500.1.20

DISTRIBUTION LIMITATIONS:
None; obtain copies from DDC.

UNCLASSIFIED

AD- ACCESSION NO.

FRANKFORD ARSENAL, Research and Development Group, Pitman-Dunn Institute for Research, Philadelphia, Pa.

PYROTECHNIC DELAY DEVICES FOR LOW ENERGY DETONATING CORD SYSTEMS by J. F. Kowalick

Unclassified Report

FA Rpt M64-26-1, Apr 64; 22 pp incl illustrations

OMS Code 4110.16.8500.1.20

A study was initiated to survey the field of pyrotechnic delay devices as they pertain to systems where relatively low energy transfer is accomplished through detonating cord having a core of small amounts of high explosive. Detonating fuse delays developed for use in the blasting industry incorporate powder trains of the sequence - high explosive to deflagrating composition, to delay composition. Although such delays appear to be in common use, their delay times do not exceed approximately 300 msec, and their reliability has not been established.

Furthermore, a design problem may exist in scaling up the delay time to the order of several seconds. Functional descriptions of these delays are presented. A method is presented for providing a complete seal between detonating cord and the delay device.

References cited, although not all-inclusive, are indicative of current and past interest in this subject.

UNCLASSIFIED

1. Aircraft Escape Systems
2. LEDC
3. Delays

I. FA Rpt M64-26-1, Apr 64
II. J. F. Kowalick
III. OMS Code 4110.16.8500.1.20

DISTRIBUTION LIMITATIONS:
None; obtain copies from DDC.

UNCLASSIFIED

AD- ACCESSION NO.

FRANKFORD ARSENAL, Research and Development Group, Pitman-Dunn Institute for Research, Philadelphia, Pa.

PYROTECHNIC DELAY DEVICES FOR LOW ENERGY DETONATING CORD SYSTEMS by J. F. Kowalick

Unclassified Report

FA Rpt M64-26-1, Apr 64; 22 pp incl illustrations

OMS Code 4110.16.8500.1.20

A study was initiated to survey the field of pyrotechnic delay devices as they pertain to systems where relatively low energy transfer is accomplished through detonating cord having a core of small amounts of high explosive. Detonating fuse delays developed for use in the blasting industry incorporate powder trains of the sequence - high explosive to deflagrating composition, to delay composition. Although such delays appear to be in common use, their delay times do not exceed approximately 300 msec, and their reliability has not been established.

Furthermore, a design problem may exist in scaling up the delay time to the order of several seconds. Functional descriptions of these delays are presented. A method is presented for providing a complete seal between detonating cord and the delay device.

References cited, although not all-inclusive, are indicative of current and past interest in this subject.

UNCLASSIFIED

1. Aircraft Escape Systems
2. LEDC
3. Delays

I. FA Rpt M64-26-1, Apr 64
II. J. F. Kowalick
III. OMS Code 4110.16.8500.1.20

DISTRIBUTION LIMITATIONS:
None; obtain copies from DDC.

UNCLASSIFIED

AD- ACCESSION NO.

FRANKFORD ARSENAL, Research and Development Group, Pitman-Dunn Institute for Research, Philadelphia, Pa.

PYROTECHNIC DELAY DEVICES FOR LOW ENERGY DETONATING CORD SYSTEMS by J. F. Kowalick

Unclassified Report

FA Rpt M64-26-1, Apr 64; 22 pp incl illustrations

OMS Code 4110.16.8500.1.20

A study was initiated to survey the field of pyrotechnic delay devices as they pertain to systems where relatively low energy transfer is accomplished through detonating cord having a core of small amounts of high explosive. Detonating fuse delays developed for use in the blasting industry incorporate powder trains of the sequence - high explosive to deflagrating composition, to delay composition. Although such delays appear to be in common use, their delay times do not exceed approximately 300 msec, and their reliability has not been established.

Furthermore, a design problem may exist in scaling up the delay time to the order of several seconds. Functional descriptions of these delays are presented. A method is presented for providing a complete seal between detonating cord and the delay device.

References cited, although not all-inclusive, are indicative of current and past interest in this subject.

UNCLASSIFIED

1. Aircraft Escape Systems
2. LEDC
3. Delays

I. FA Rpt M64-26-1, Apr 64
II. J. F. Kowalick
III. OMS Code 4110.16.8500.1.20

DISTRIBUTION LIMITATIONS:
None; obtain copies from DDC.

UNCLASSIFIED

AD- ACCESSION NO.

FRANKFORD ARSENAL, Research and Development Group, Pitman-Dunn Institute for Research, Philadelphia, Pa.

PYROTECHNIC DELAY DEVICES FOR LOW ENERGY DETONATING CORD SYSTEMS by J. F. Kowalick

Unclassified Report

FA Rpt M64-26-1, Apr 64; 22 pp incl illustrations

OMS Code 4110.16.8500.1.20

A study was initiated to survey the field of pyrotechnic delay devices as they pertain to systems where relatively low energy transfer is accomplished through detonating cord having a core of small amounts of high explosive. Detonating fuse delays developed for use in the blasting industry incorporate powder trains of the sequence - high explosive to deflagrating composition, to delay composition. Although such delays appear to be in common use, their delay times do not exceed approximately 300 msec, and their reliability has not been established.

Furthermore, a design problem may exist in scaling up the delay time to the order of several seconds. Functional descriptions of these delays are presented. A method is presented for providing a complete seal between detonating cord and the delay device.

References cited, although not all-inclusive, are indicative of current and past interest in this subject.

UNCLASSIFIED

1. Aircraft Escape Systems
2. LEDC
3. Delays

I. FA Rpt M64-26-1, Apr 64
II. J. F. Kowalick
III. OMS Code 4110.16.8500.1.20

DISTRIBUTION LIMITATIONS:
None; obtain copies from DDC.

UNCLASSIFIED

AD- ACCESSION NO.

FRANKFORD ARSENAL, Research and Development Group, Pitman-Dunn Institute for Research, Philadelphia, Pa.

PYROTECHNIC DELAY DEVICES FOR LOW ENERGY DETONATING CORD SYSTEMS by J. F. Kowalick

Unclassified Report

FA Rpt M64-26-1, Apr 64; 22 pp incl illustrations

OMS Code 4110.16.8500.1.20

A study was initiated to survey the field of pyrotechnic delay devices as they pertain to systems where relatively low energy transfer is accomplished through detonating cord having a core of small amounts of high explosive. Detonating fuse delays developed for use in the blasting industry incorporate powder trains of the sequence - high explosive to deflagrating composition, to delay composition. Although such delays appear to be in common use, their delay times do not exceed approximately 300 msec, and their reliability has not been established.

Furthermore, a design problem may exist in scaling up the delay time to the order of several seconds. Functional descriptions of these delays are presented. A method is presented for providing a complete seal between detonating cord and the delay device.

References cited, although not all-inclusive, are indicative of current and past interest in this subject.

UNCLASSIFIED

1. Aircraft Escape Systems
2. LEDC
3. Delays

I. FA Rpt M64-26-1, Apr 64
II. J. F. Kowalick
III. OMS Code 4110.16.8500.1.20

DISTRIBUTION LIMITATIONS:
None; obtain copies from DDC.

UNCLASSIFIED

UNCLASSIFIED

UNCLASSIFIED